R&D Project Review of Food Industry Energy Research (FIER) Program
UC Davis
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Infrared Drying of Rice to Improve Energy Efficiency and Disinfestation

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USDA

UCDAVIS

Objectives

- Evaluate the performance of catalytic flameless gas-fired infrared dryer (CFGIR) and electric infrared dryer for rice and onion drying
- Evaluate the effectiveness of infrared heating for rice disinfestation

Outlines

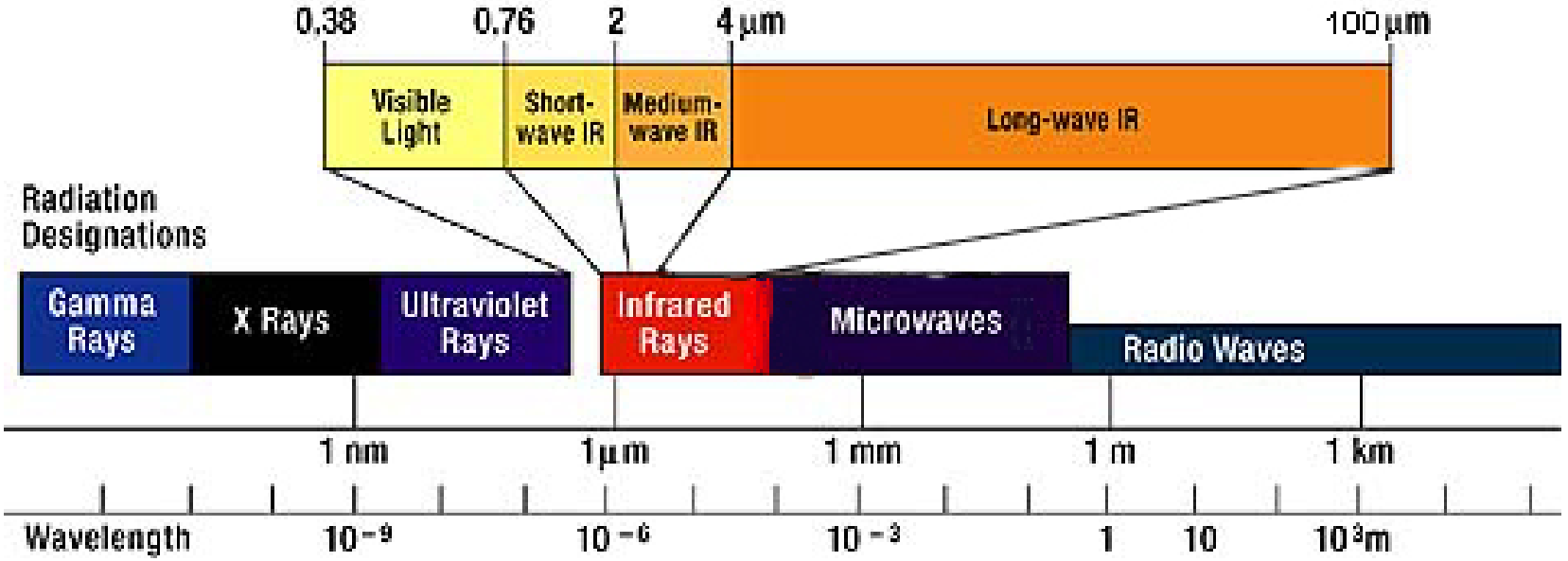
- Principles of infrared radiation
- Performance of catalytic flameless gas-fired infrared dryer (CFGIR) for rice and onion drying
- Performance of electric infrared dryer for rice and onion drying
- Other potential applications of infrared
  - Blanching and dehydration of fruits and vegetables

Infrared Technology

- Infrared radiant heat transfer is often more efficient than convective heat transfer
- Produce virtually no volatile organic compounds (VOC), carbon monoxide (CO), and nitrogen oxides (NO_X)
- Limited uses of infrared radiation in food and agricultural processing

Principles of Infrared

- Infrared radiation – Electromagnetic wave



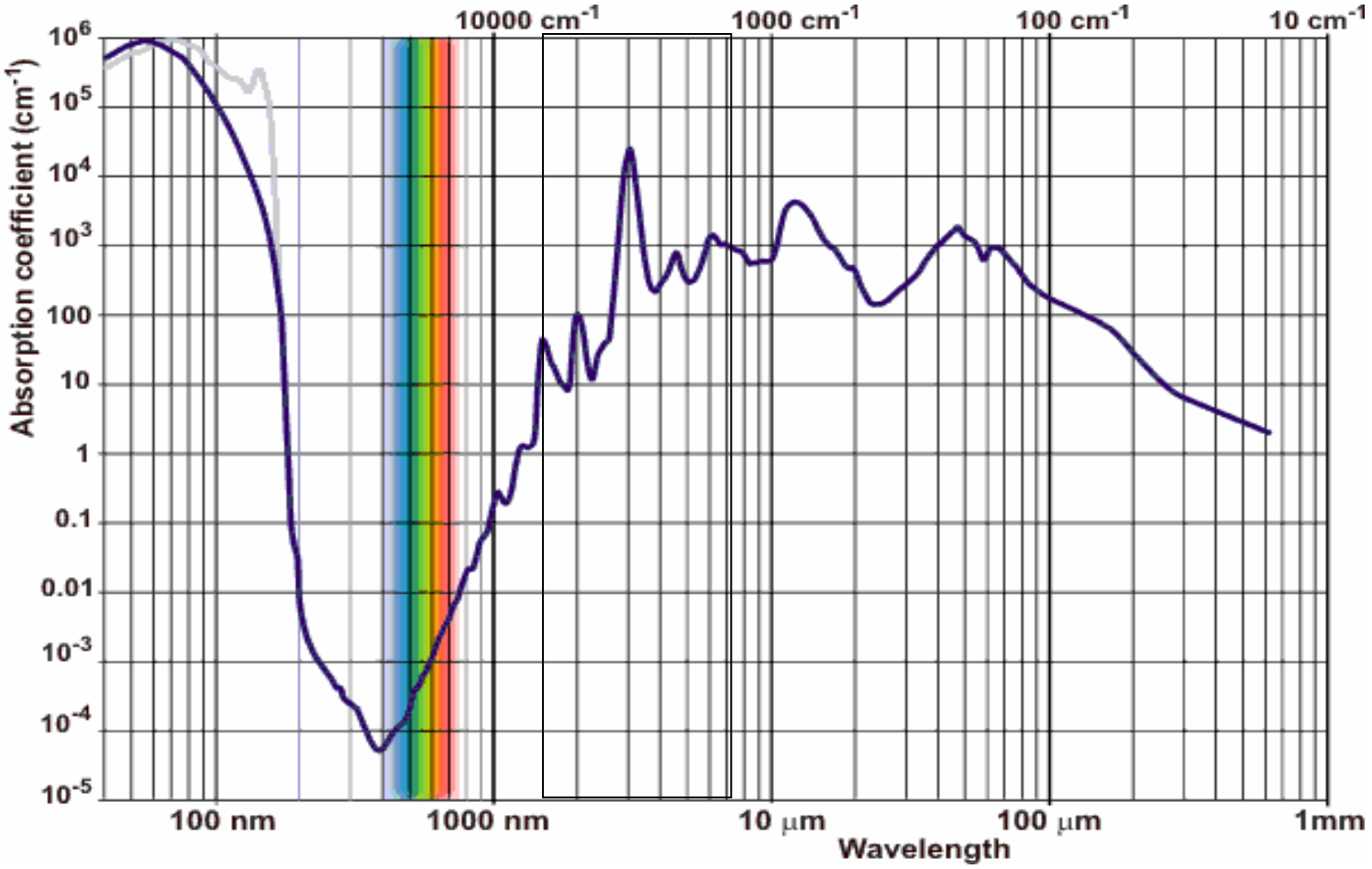
Electromagnetic spectrum

Principles of Infrared

Peak wavelengths and temperatures of a blackbody

	Wavelength (μm)	Temperature	
Near infrared (NIR)	0.8 – 2	3623 -1448 K	3350 -1175°C
Medium infrared (MIR)	2 – 4	1448 – 723 K	1175 - 450°C
Far infrared (FIR)	4 – 100	723 – 28 K	450 - -245°C

Spectrum of Water 水吸收光谱



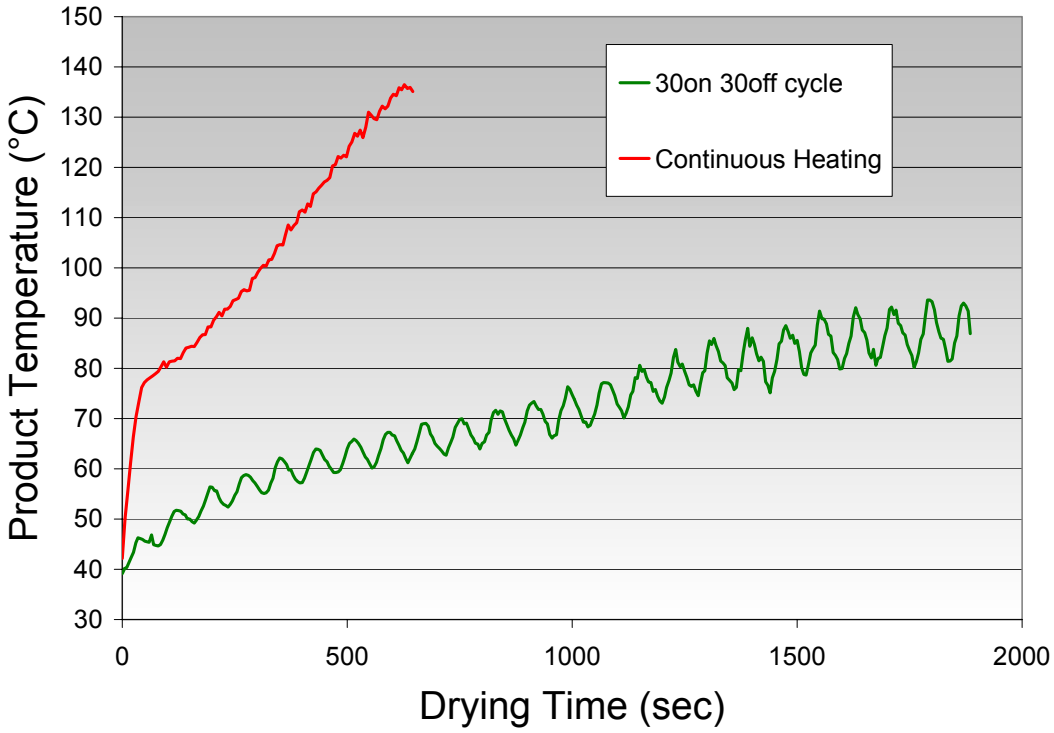
Infrared Radiation Drying

Heating Methods加热方式

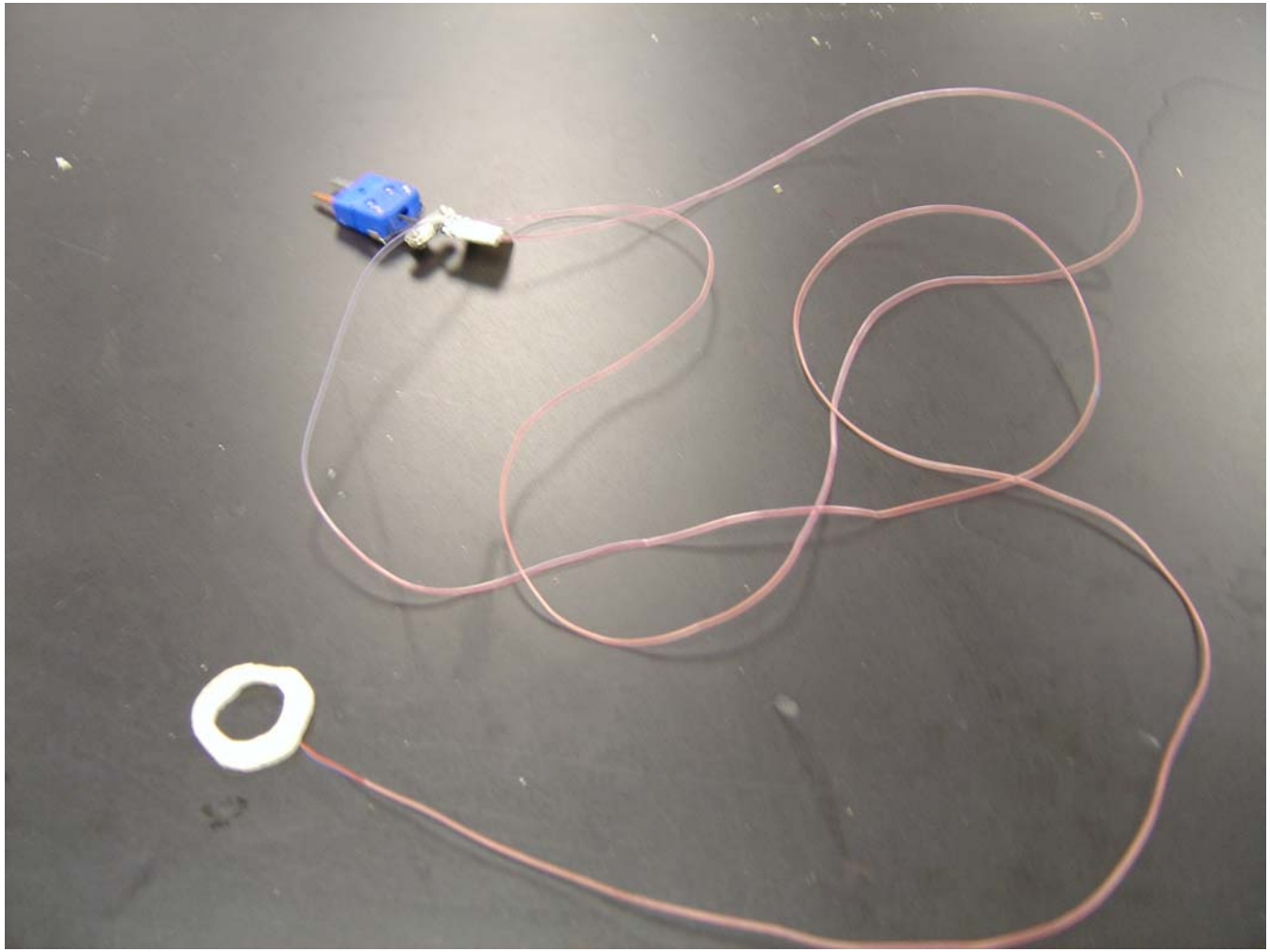
- Continuous heating 连续加热
- Intermittent heating 间歇加热
  - Fixed heating cycle 固定间歇加热
  - Variable heating cycle 变频间接加热
    - Recirculation fan on
    - Recirculation fan off

Infrared Radiation Drying

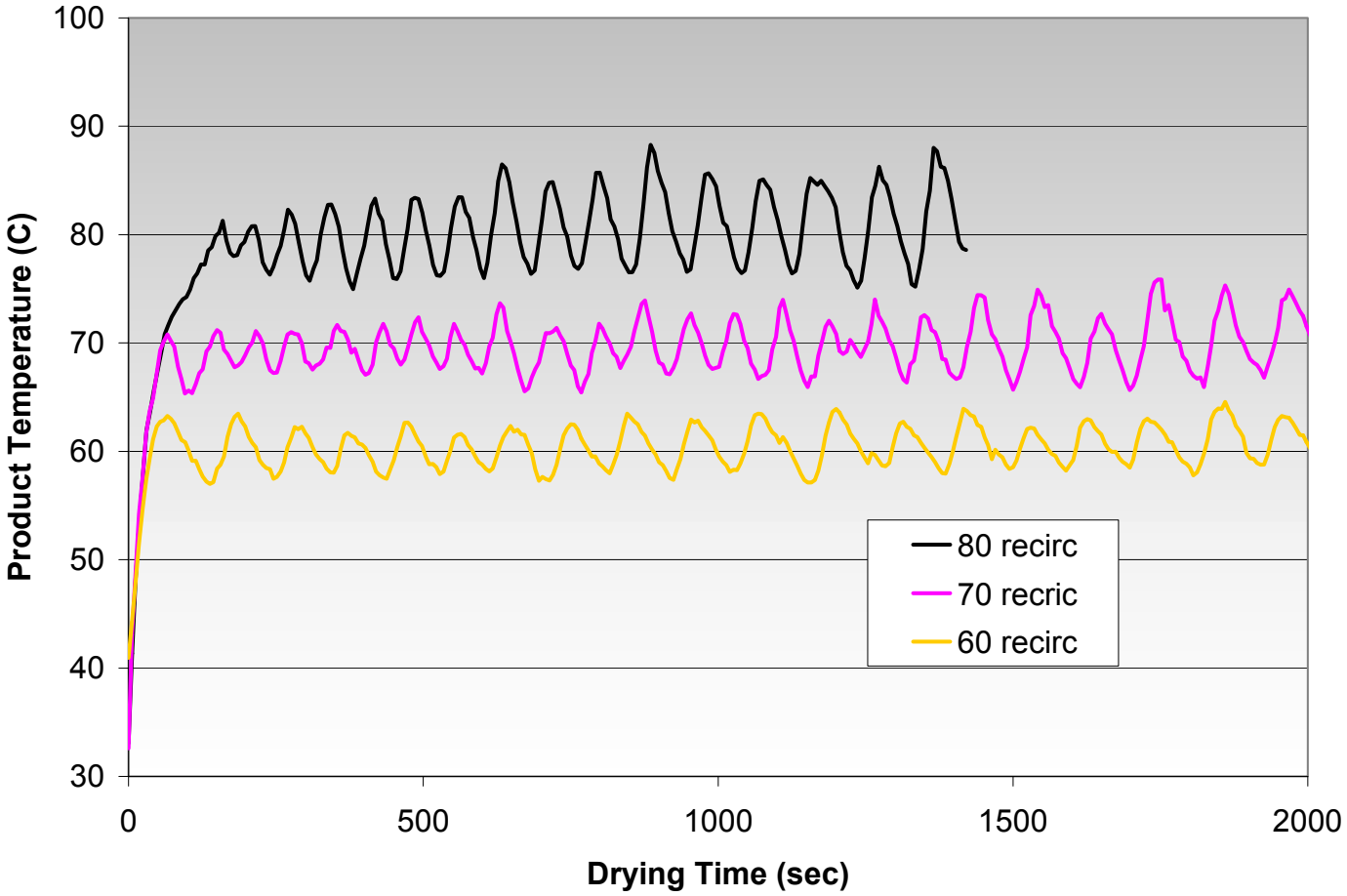
Product Temperatures – Continuous & Fixed Cycle Drying



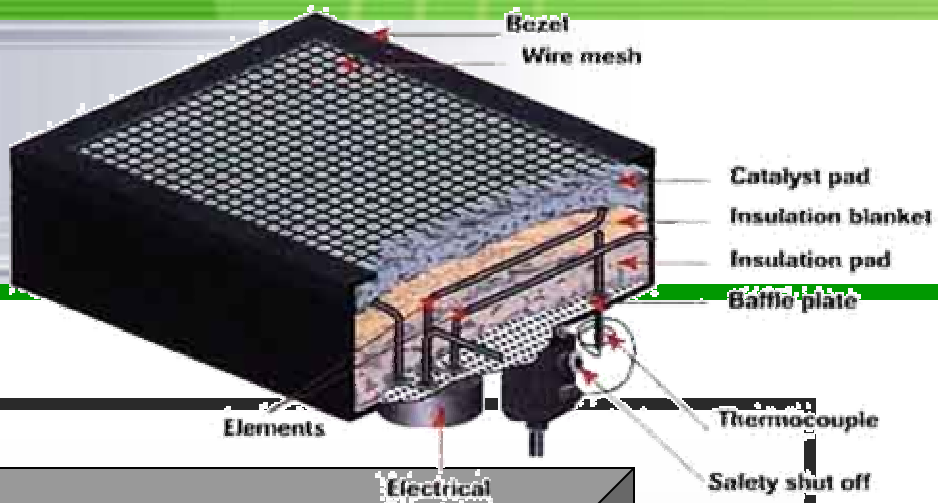
Infrared Radiation Drying



Product Temperatures Under Controlled Condition



CFGIR Emitter



Gas line

Heating element

Insulation

Insulation

Catalyst

CO_2 + H_2O vapor

T=350 – 600°C

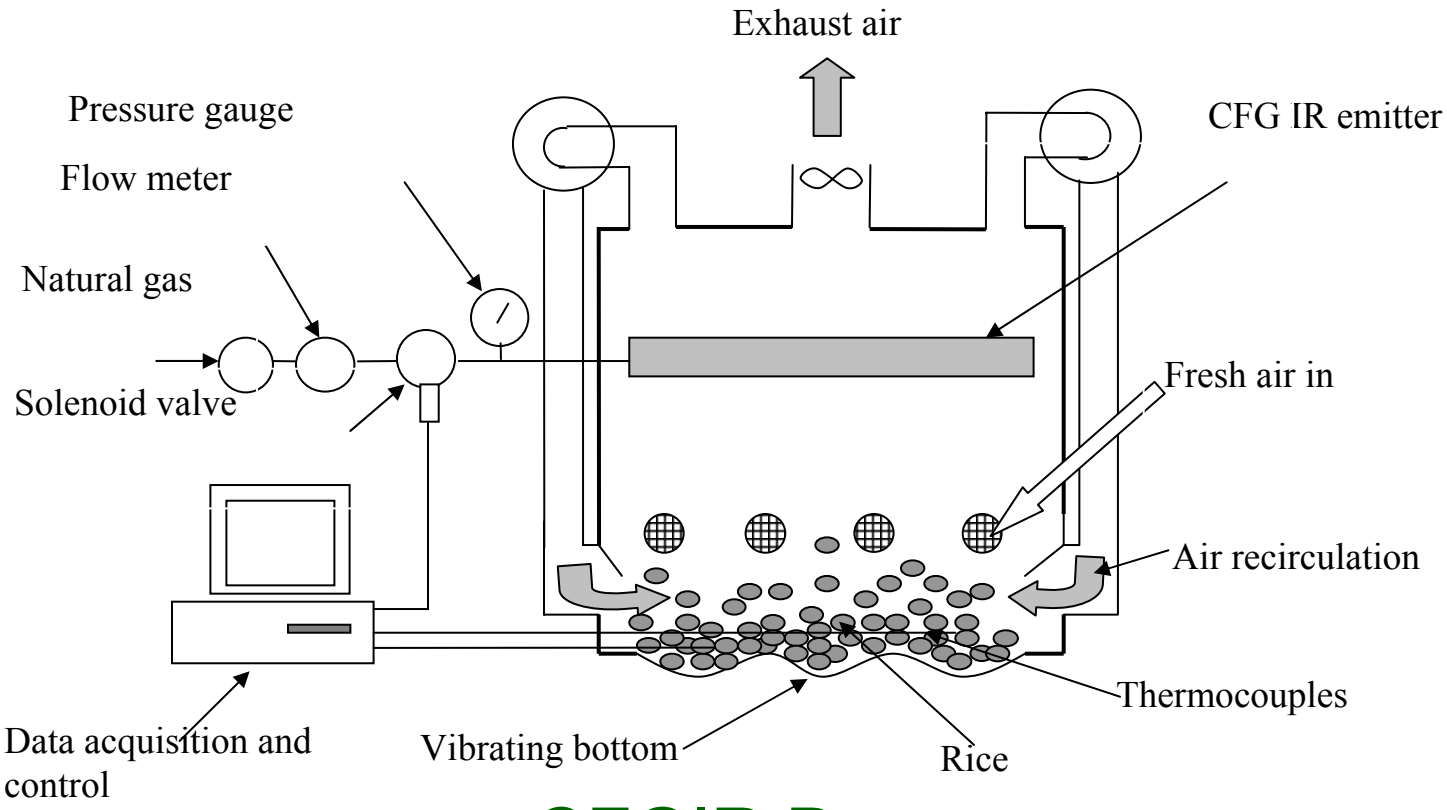
Stainless steel screen

Infrared Dryers

Electric vacuum infrared dryer

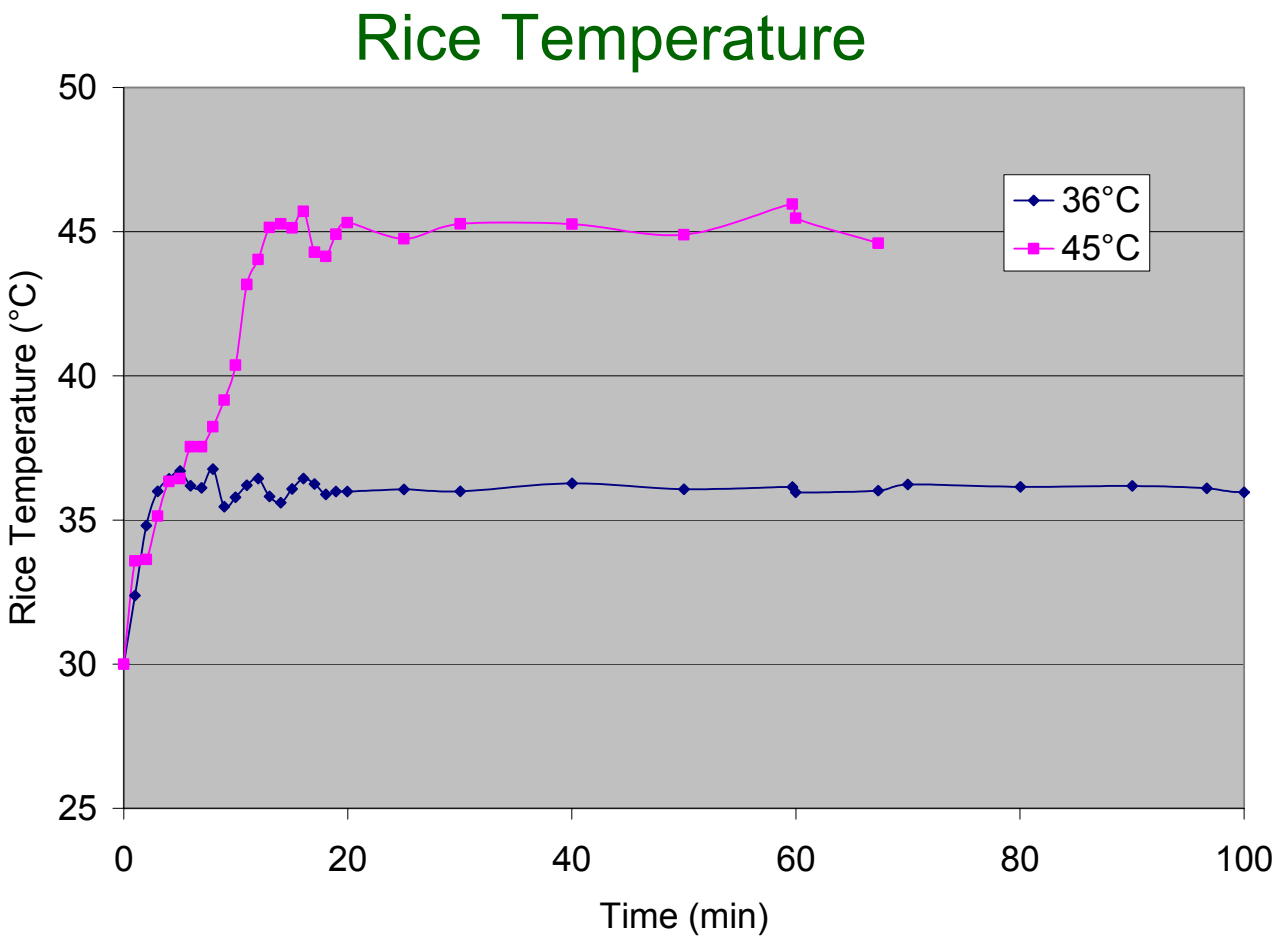
Catalytic flameless gas-fired infrared (CFGIR) dryer

CFGIR Radiation Drying - Rice



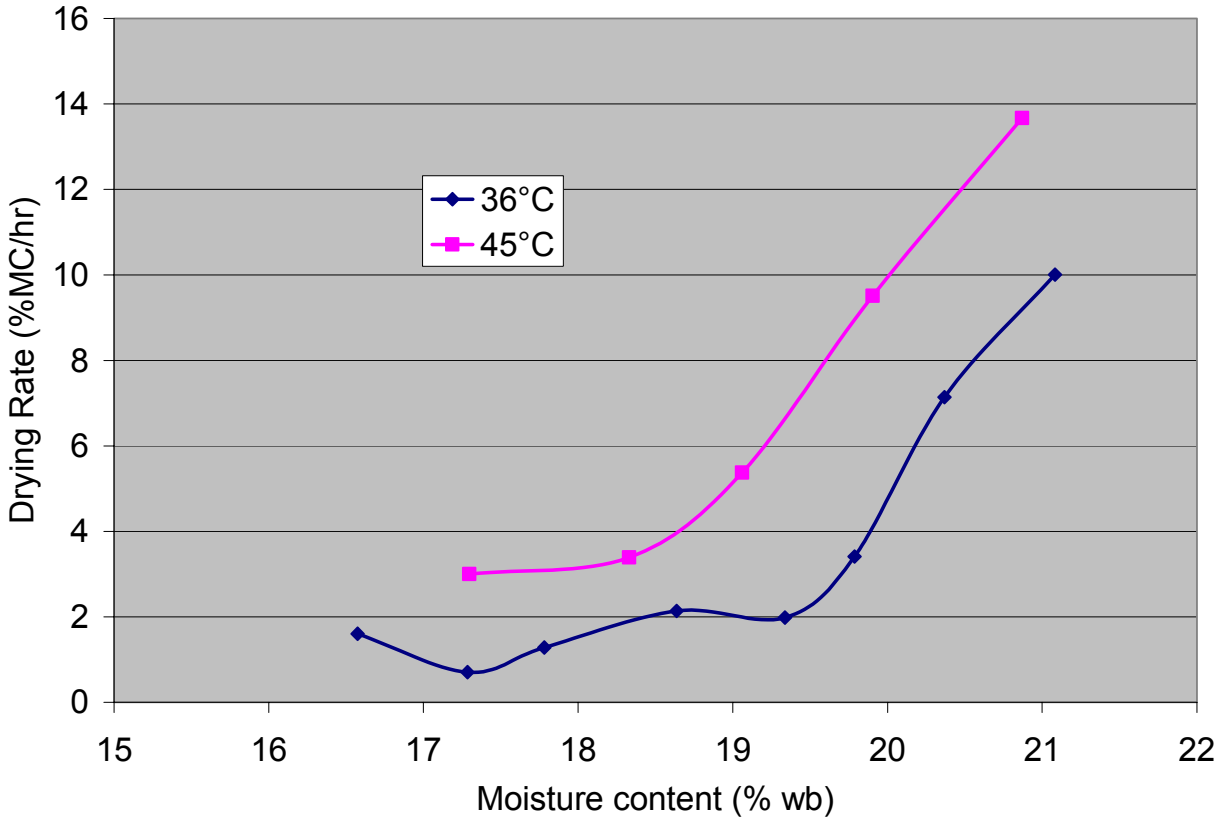
CFGIR Dryer

CFGIR Radiation Drying - Rice



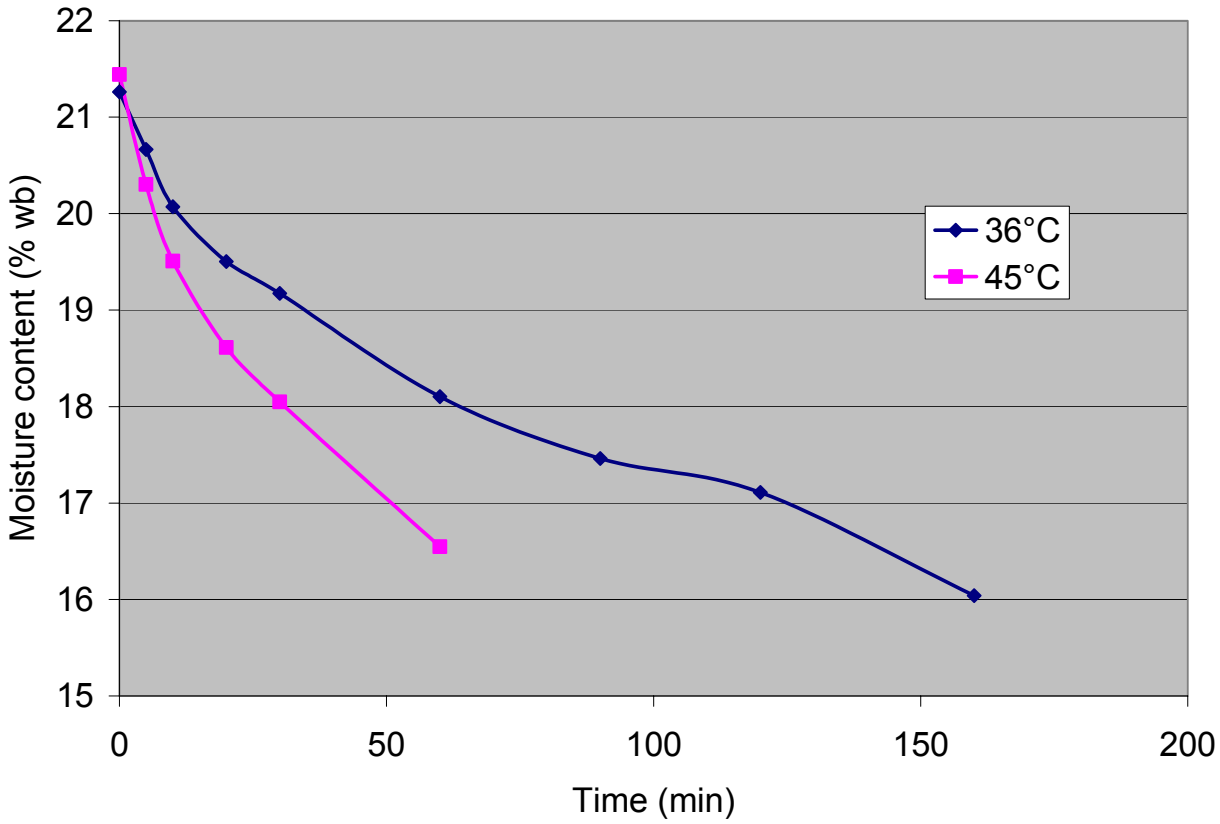
CFGIR Radiation Drying - Rice

Rice Drying Rate



CFGIR Radiation Drying - Rice

Rice Moisture Change



CFGIR Radiation Drying - Rice

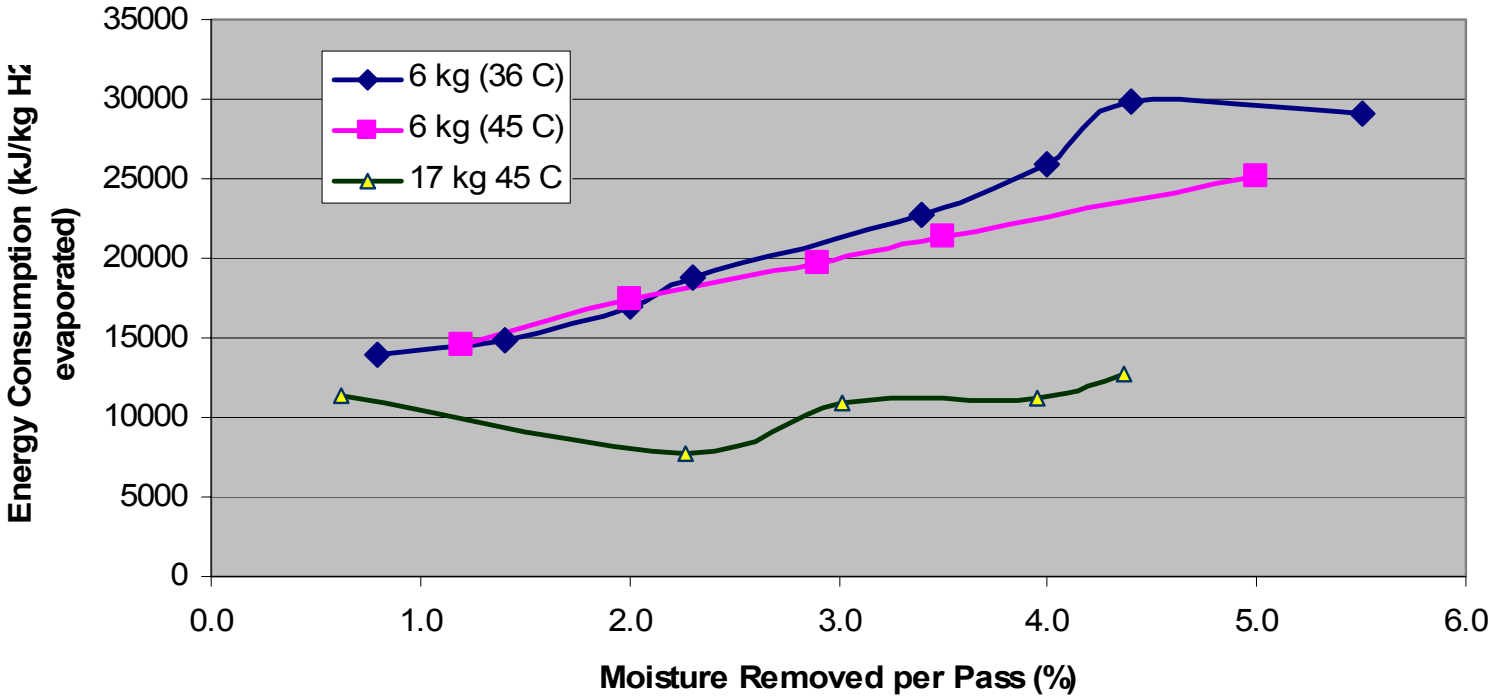
Rice Quality – Head Rice Yield

	Drying Conditions					
	36° C		45° C		54° C	
MC removal (%)	T	NT	T	NT	T	NT
2.5			62.9	62.0	61.1	60.1
5	61.3	61.6	60.3	56.2	48.9	32.8
7	58.7	53.5	36.9	27.8	30.2	18.3

T – Tempering
NT – No Tempering

CFGIR Radiation Drying - Rice

Energy Consumption



CFGIR Radiation Drying - Rice

Drying Cost and Saving

Energy cost of drying paddy by Gas and Electricity

Initial weight = 1000 kg (1 Ton)

Drying Rice from 24 % to 13% ⇨ need to remove 126.4 kg water ⇨ need 2.64 Therm. or 77.3 kWh

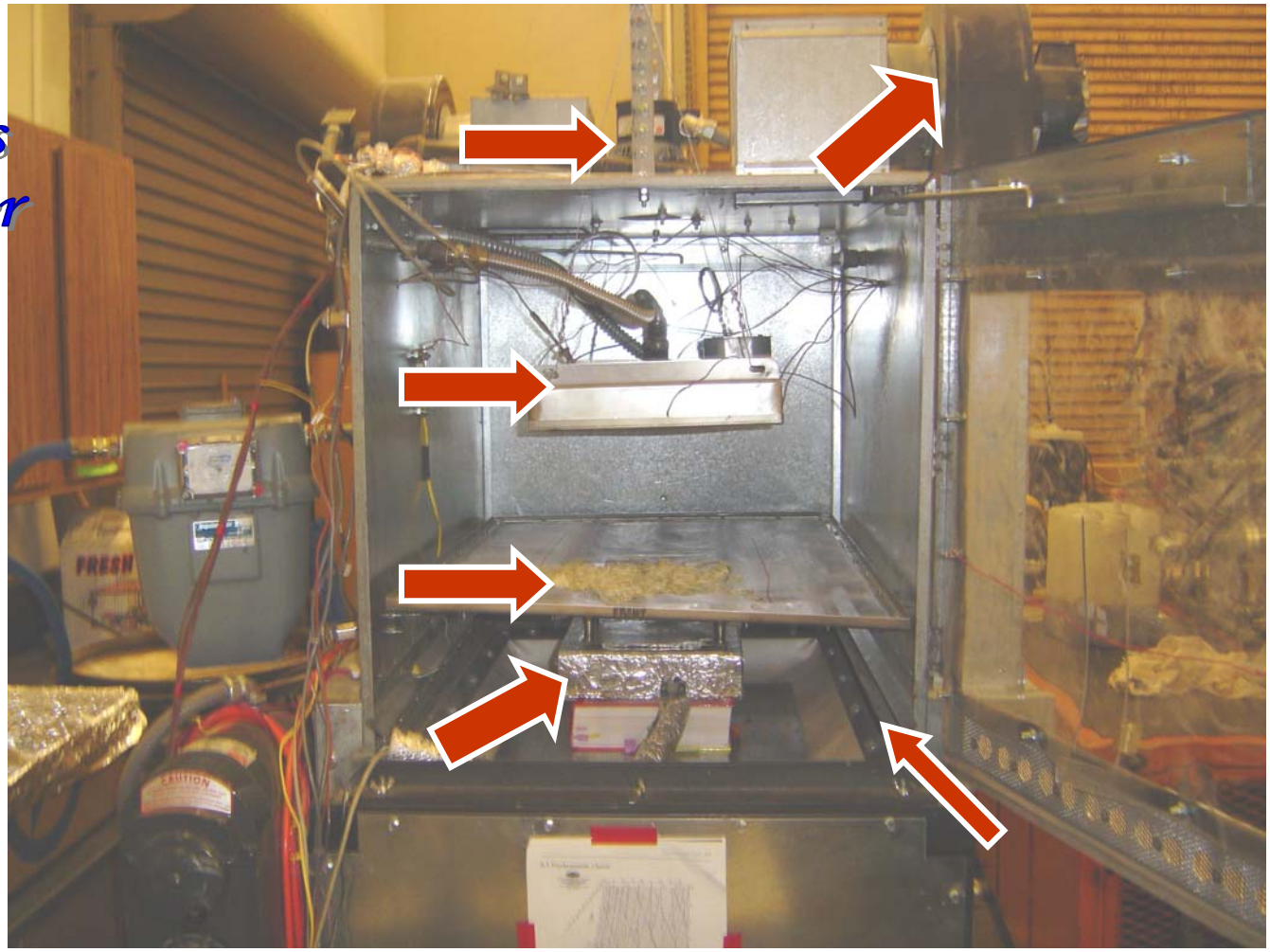
Assume: Cost of natural gas = $ 0.60/ Therm

Cost of Electricity = $ 0.10 / kW.h

	Natural gas	Electricity	Total cost ($)	Saving
Current drying method	**72%**	**28%**	**3.30**	
IR drying method	**85%**	**15%**	**2.51**	**$0.79 or 24%**

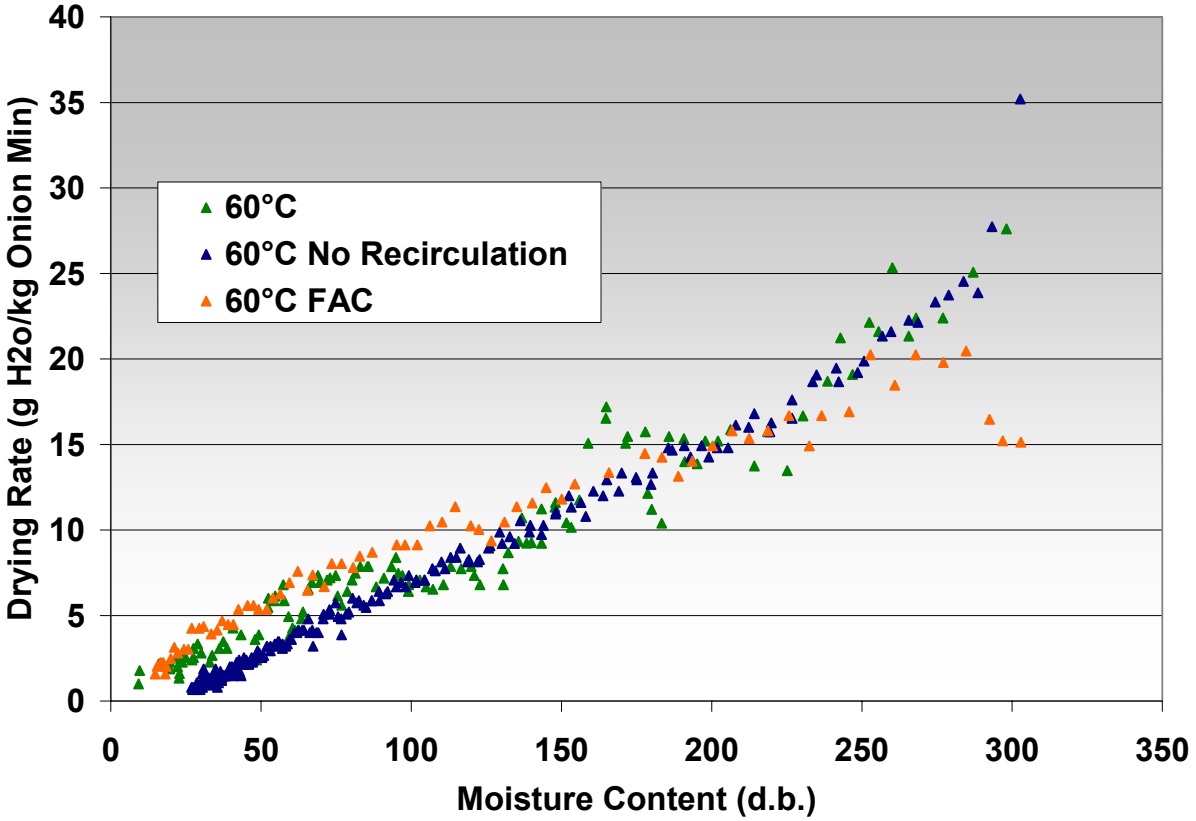
CFGIR Radiation Drying - Onion

Catalytic Flameless Gas Infrared Drier (CFGIR)



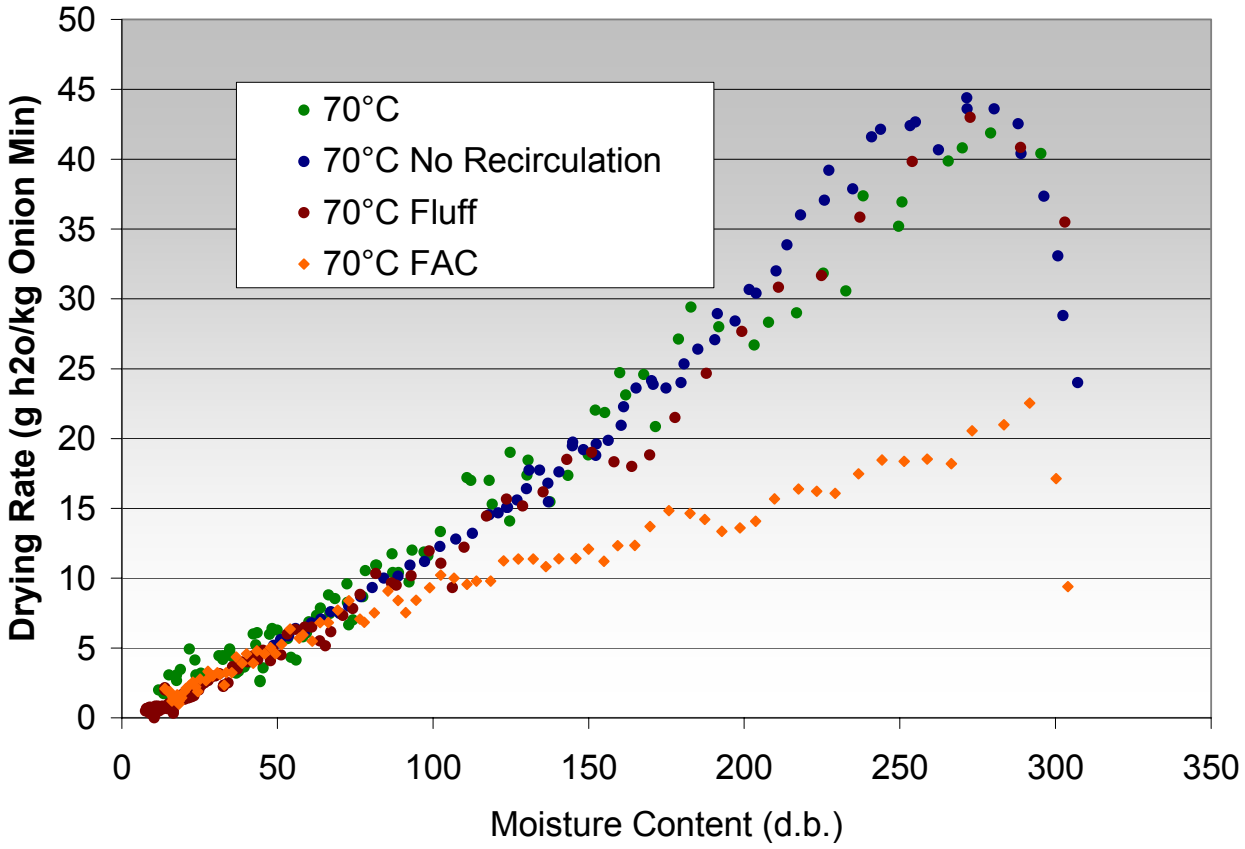
CFGIR Radiation Drying - Onion

DRYING RATES – 60°C



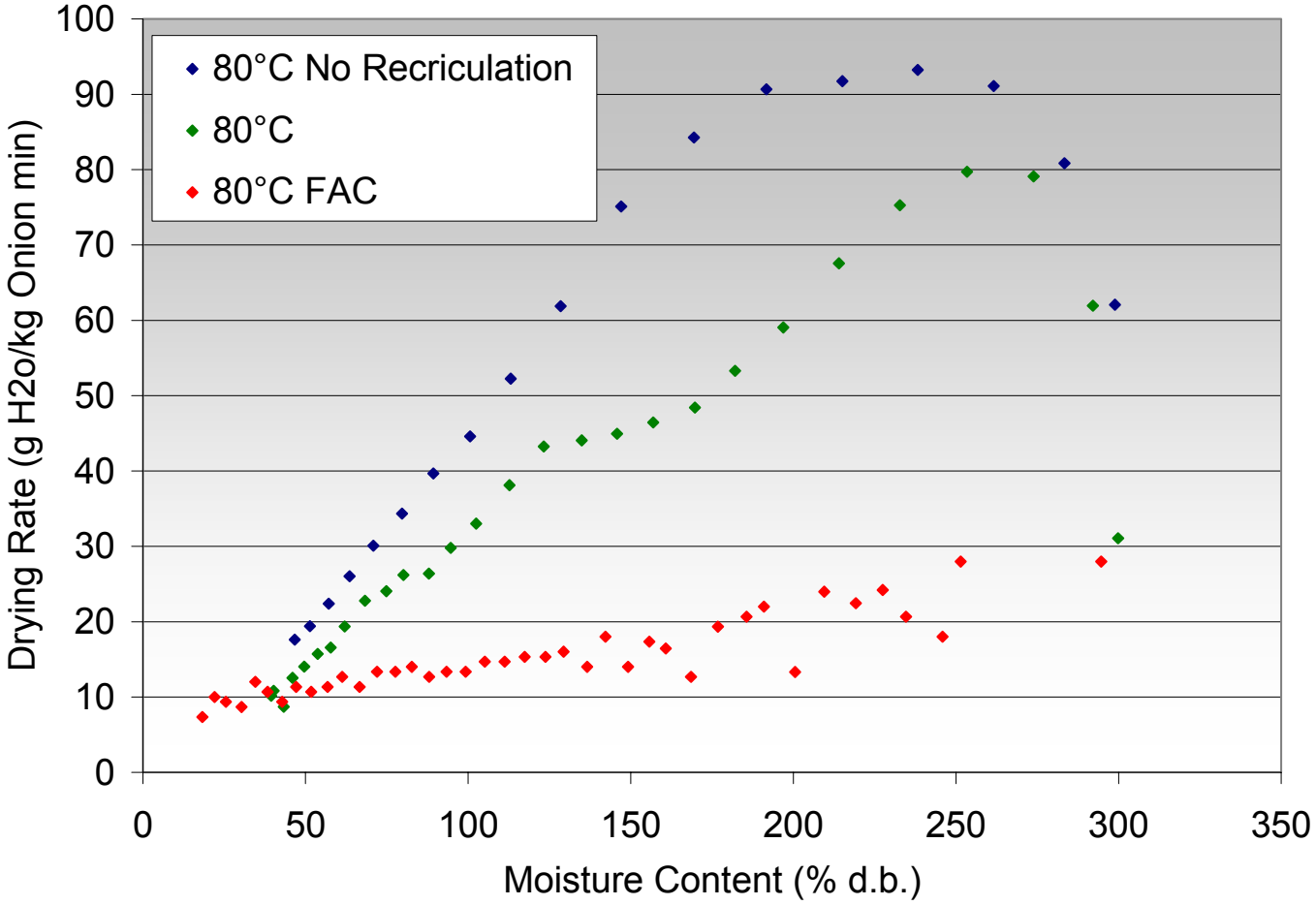
CFGIR Radiation Drying - Onion

DRYING RATES – 70°C



CFGIR Radiation Drying - Onion

DRYING RATES – 80°C



CFGIR Radiation Drying - Onion

Color Comparison

Electric IR Radiation Drying

Electric infrared dryer with vacuum

Advantage:

Fast drying rate

Disadvantages:

Low loading ratio

Difficult to handle the product

Electric IR Radiation Drying

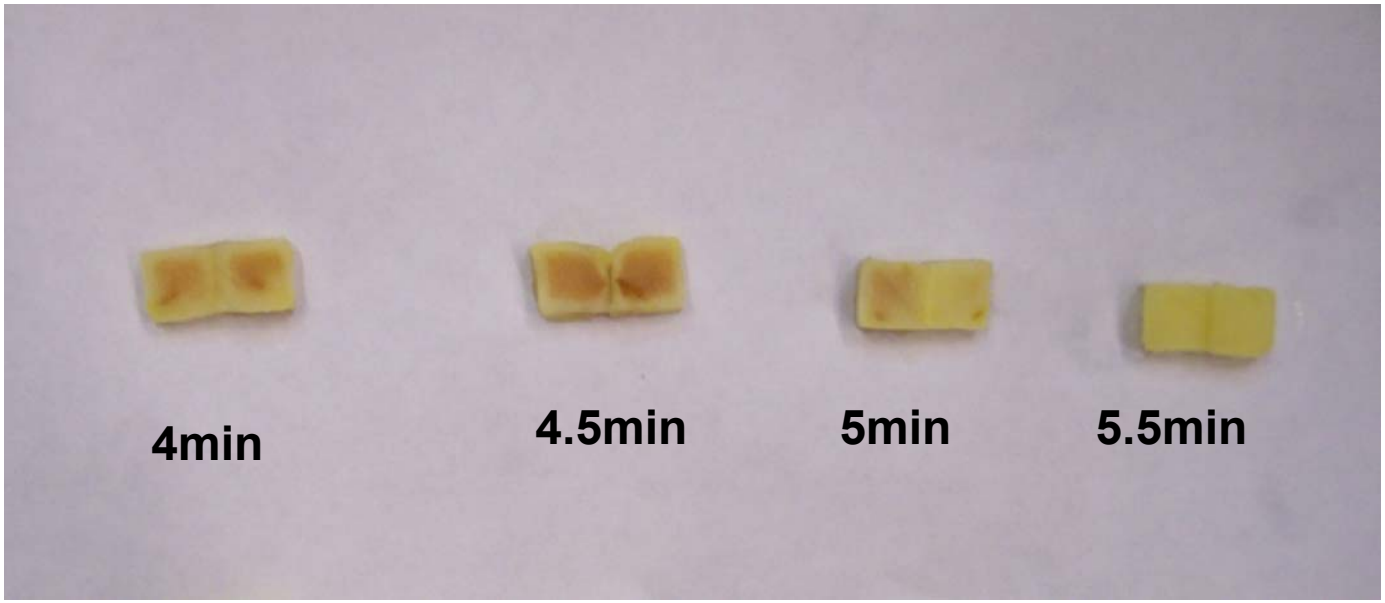
New electric infrared dryer with vacuum

Infrared Dry Blanching (IDB)

Infrared Blancher/dryer

Infrared Dry Blanching (IDB)

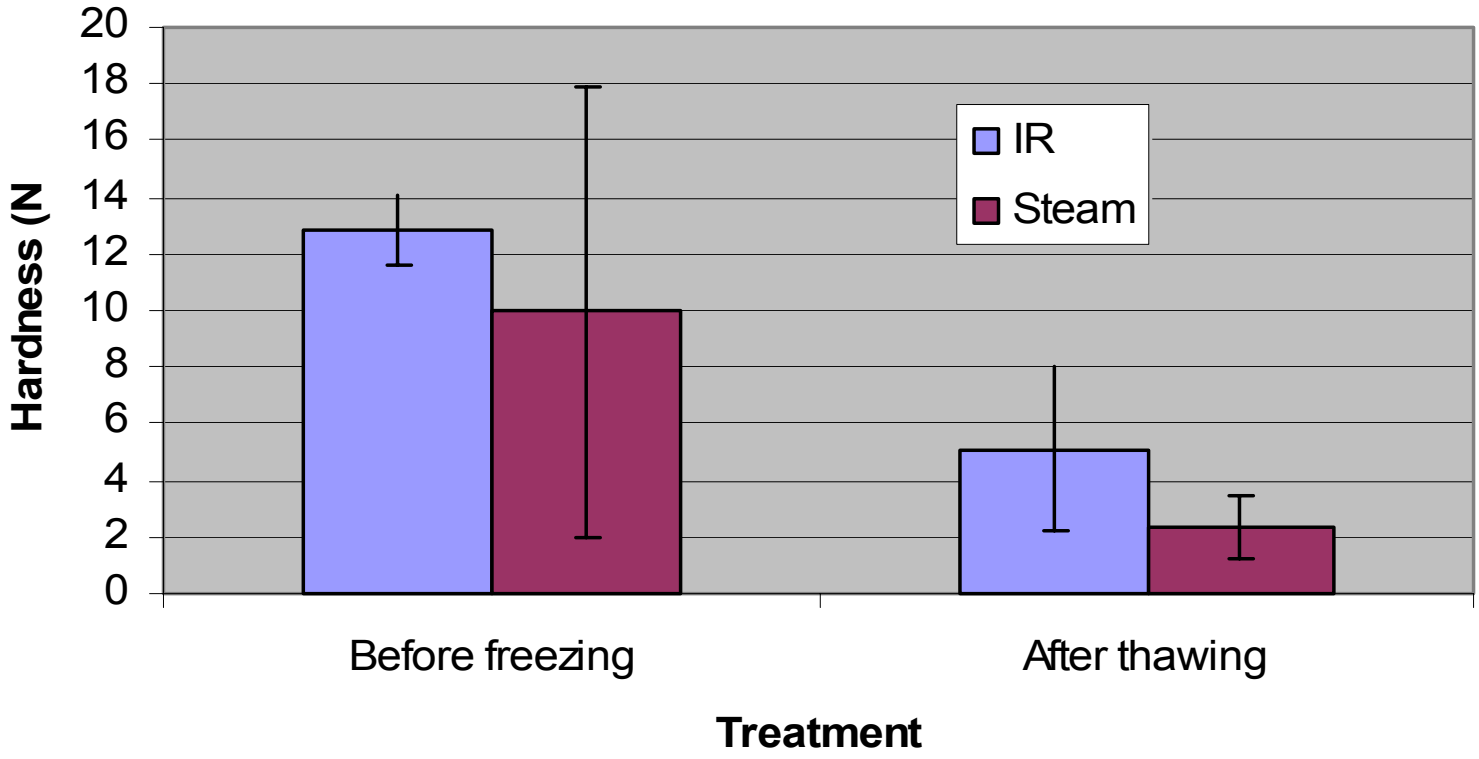
- Apple samples



Enzymatic (peroxidase) activity of treated with IDB for various times
½” (12.7mm cubes)

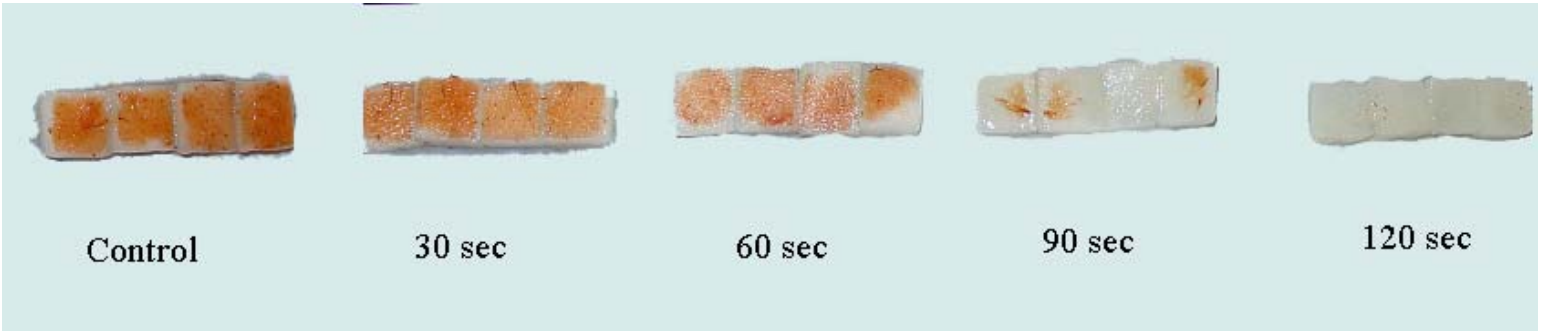
Infrared Dry Blanching (IDB)

- Texture of IDB and Steam Blanched Apple Samples



Infrared Dry Blanching (IDB)

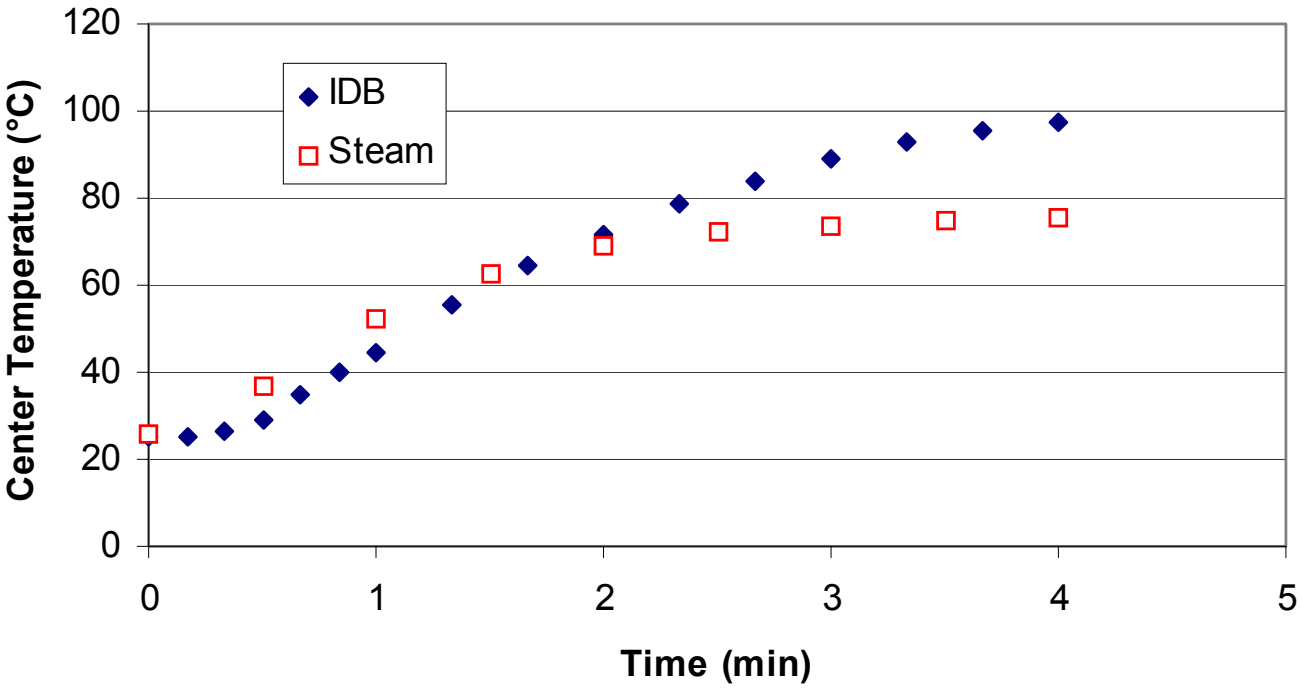
- Pear samples



Enzymatic (peroxidase) activity of treated with IDB for various times ½" (12.7mm cubes)

Infrared Dry Blanching (IDB)

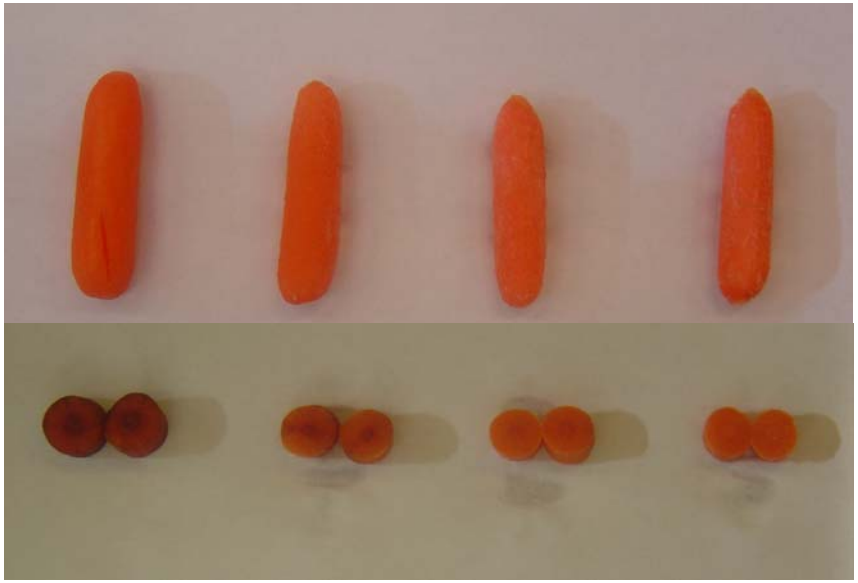
•Pear samples 热传递



Heating rates of pear slices by IDB and 75° C steam blanching

Infrared Dry Blanching (IDB)

- Carrots

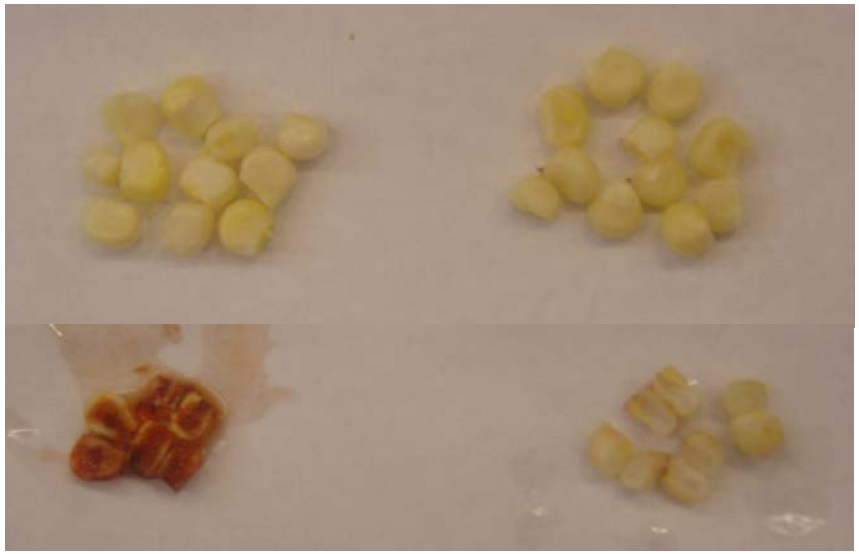


Control 2min 3min 4min

Enzymatic (peroxidase) activity of treated with IDB for various times (15mm in Diameter)

Infrared Dry Blanching (IDB)

- Cut corn (corn kernels)

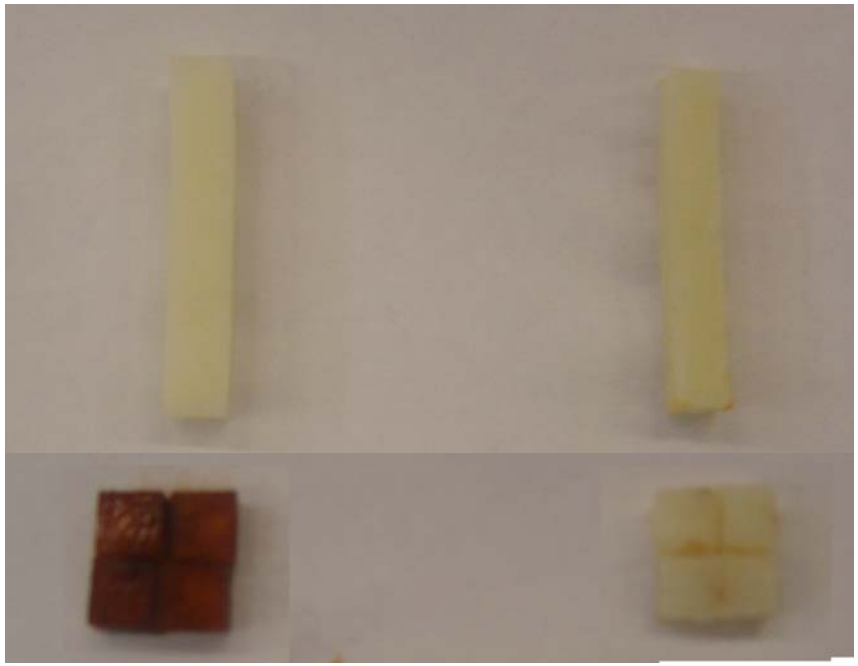


Control 1min

Enzymatic (peroxidase) activity of treated with IDB for various times

Infrared Dry Blanching (IDB)

- French Fries

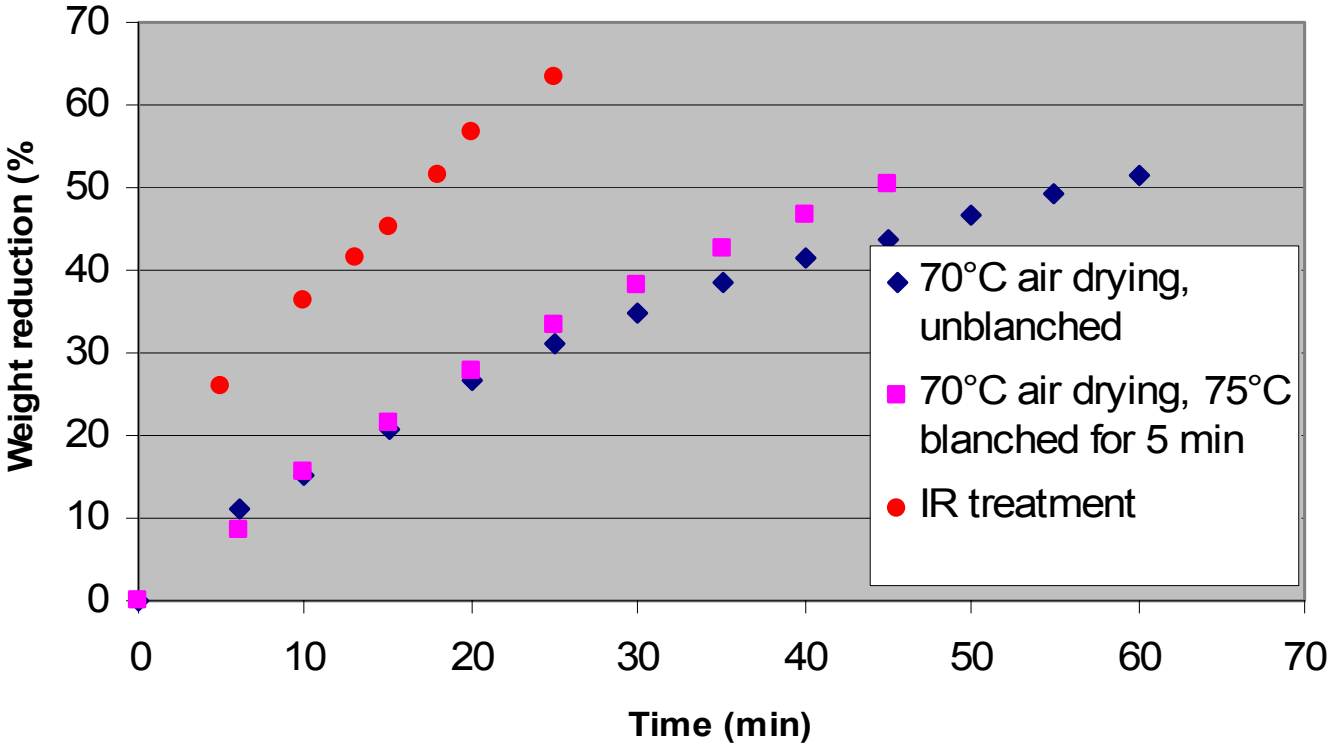


Control 3.5min

Enzymatic (peroxidase) activity of treated with IDB for various times

Infrared Dry Blanching (IDB)

Simultaneous Blanching and Dehydration of Pears



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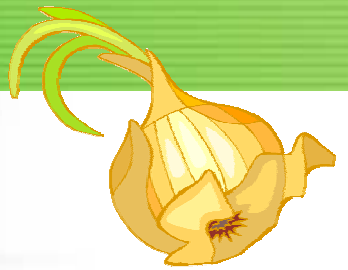

Thank You

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